Working document presented in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9 (WGACEGG). Online meeting, 16-20 November 2020.

Exploration of historical data and potential solution for the missing information in the Iberian sardine DEPM survey (SAREVA 0320) caused by the COVID-19 pandemic crisis.

Paz Díaz[1], Rosario Domínguez-Petit[1], Maria Manuel Angélico[2], Cristina Nunes[2] and Pablo Carrera[1]

[1]Instituto Español de Oceanografía (IEO), Centro Oceanográfico Costero de Vigo.
[2]Instituto Portugués do Mar e da Atmosfera (IPMA), Lisboa.

Abstract

As part of the Iberian DEPM survey for sardine (*Sardina pilchardus)*, two surveys are carried out every three years by Portugal (IPMA; PT-DEMP-PIL) and Spain (IEO; SAREVA). The total spawning biomass from the two DEPM surveys is used in the assessment such as fishery independent index for the sardine stock pil.27.8c9a (ICES divisions 8.c and 9.a -Cantabrian Sea and Atlantic Iberian waters). In 2020 both surveys were planned and coordinated under the framework of the ICES WGACEGG. The Portuguese survey was successfully conducted, however, the Spanish survey; SAREVA0320, was cancelled due to the COVID-19 health crisis and the subsequent 'state of alarm' lockdown in Spain.

This working document provides a description of methods explored to compensate the lack of data in ICES areas 9aN and 8c caused by the cancelation of sardine DEPM survey "SAREVA 0320". After checking that sardine egg data obtained from the anchovy DEPM survey, delivered in a partial area of division 8c during May by AZTI Tecnalia (BIOMAN), were not adequate for extrapolating to the SAREVA surveyed area, alternative analysis were presented based on i) sardine eggs historic data from the CUFES sampler used in the acoustic Spanish surveys PELACUS and ii) spawning stock biomass data from the Portuguese survey PT-DEPM-PIL and the Spanish survey SAREVA. A methodological approach similar to those adopted in the last sardine assessment (ICES, 2020) to face the problem of the acoustic lack of data in 2020 in subdivisions 9aN and division 8c, is described, reasoned and suggested as a solution to face the lack of Spanish data for sardine stock assessment in 2020.

Introduction

The daily egg production method (DEPM; Lasker, 1985) estimates spawning stock biomass (SSB) and together with the acoustic estimates (Simmonds and MacLennan, 2005), are currently used as fishery independent indices for assessing SSB of sardine (*Sardina pilchardus*) in ICES divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters). In this area the DEPM was first applied to sardine in 1988 (Miranda et al., 1990; Cunha et al., 1992; García et al., 1992) and regularly since the late 90s. The sardine DEPM surveys have been carried out triennially since 1999 in a collaborative work between Portugal (Instituto Portugués do Mar e da Atmosfera, IPMA) and Spain (Instituto Español de Oceanografía, IEO) what led to increased coordination and standardisation of the surveys and analytical methodologies (cf. ICES, 2004, 2005, 2006, 2017, Massé et al. 2018).

The Portuguese survey (PT-DEPM-PIL) covers (Figure 1) from the Atlantic waters of the Strait of Gibraltar to the northern border of Portugal in the Minho river (ICES division 9a), while the Spanish survey (SAREVA) covers the northern area of the stock from the Minho river to the south of the Armorican shelf in French waters (ICES subdivision 9a North and division 8c). The DEPM surveys consisted of ichthyoplankton, adults and hydrographic sampling and are internationally coordinated and planned

under the framework of ICES WGACEGG (Working Group on Acoustics and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9).

Three geographical strata are considered for the Iberian Peninsula sardine data analyses according to biological/ecological reasons (Bernal *et al*., 2007): i) South (9a S), from the Strait of Gibraltar to Cape St. Vicente; ii) West (9a W), from Cape St. Vicente to the border between northern Portugal and Spain (Minho river) and iii) North (9a N & 8c), from the Spanish-Portuguese northern border to the Spanish-French Atlantic waters limit.

At present, for assessment purposes, the sardine Iberian Peninsula stock data bases (both Portuguese and Spanish data) are merged and analysed as a single dataset. Spawning area, mortality (Bernal et al., 2011) and total egg production (P_{tot}) are calculated, per stratum, as well as adult reproductive parameters (relative fecundity and spawning fraction) (ICES, 2017). The results are used to estimate the total SSB from the divisions 8.c and 9.a that will be used in the assessment, joint to the springs acoustic surveys (Spanish PELACUS and Portuguese PELAGO) SSB estimates, as tuning indices of the full stock area (ICES areas 8.c and 9.a).

In 2020, two DEPM surveys were planned in ICES divisions 8c and 9a as usual: The Portuguese (PT-DEMP20-PIL) and the Spanish (SAREVA 0320) ones. Although the Portuguese survey was successfully conducted in R/V Vizconde de Eza, between the 3rd and 29th of February, the Spanish survey, was cancelled due to the COVID-19 health crisis and the subsequent 'state of alarm' lockdown in Spain.

In May 2020 took place and *ad hoc* WGACEGG online meeting to discuss the implications of the lack of data due to the cancelation of SAREVA 0320 and PELACUS 0320 surveys. During the meeting, it was discussed the potential utility of information from BIOMAN survey (AZTI DEPM survey for anchovy) that was delivered in May, out of the main sardine spawning season that takes place in late winter-early spring. BIOMAN covers the eastern part of the Cantabrian Sea (subdivision 8.c.E) which represents only a partial area for the total traditionally surveyed area covered by SAREVA and it does not include adult sampling for reproductive parameters estimation.

This working document provides a brief description of methods explored to remedy the lack of data in ICES subdivision 9aN and division 8c caused by the cancelation of the SAREVA 0320 survey few days before its planned start in March due to the COVID-19 pandemia.

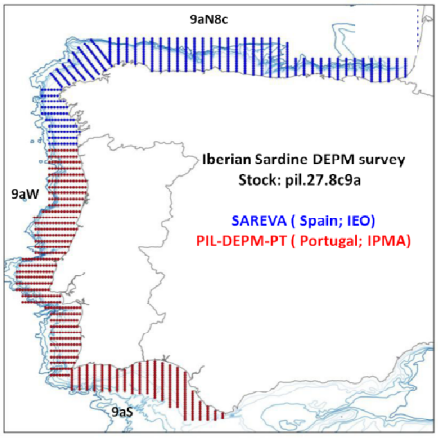

Figure 1. Area covered by the sardine DEPM surveys in ICES divisions 9a and 8c. Blue points represents the Spanish survey (IEO: SAREVA) and red points the Portuguese survey (IPMA: PIL-DEPM-PT). The three geographical strata considered for the Iberian Peninsula sardine data analyses are shown on the figure; 9aS: South, 9aW: West and 9aN8c: North.

Material and Methods

Two sets of data were analyzed to provide the sardine SSB in subdivision 9aN and division 8c for 2020.

- The data of sardine eggs recorded during the Spanish acoustic PELACUS survey sampled with CUFES (Continuous Underway Fish Egg Sampler, Checkley *et al*., 1997) between 2013 and 2019, in order to study the inter-annual egg sardine distribution variability along the subdivision 9aN and division 8c.

- The SSB series estimated from the PT-DEMP-PIL and SAREVA DEPM surveys in order to study the contribution of each stratum to the total SSB index, their correlation and the regression model to scale up the SSB estimated from the Portuguese survey to the total SSB.

Analysis of sardine eggs from CUFES in PELACUS (2013-2019)

The centre of gravity of eggs sampled with CUFES during the acoustic PELACUS survey from 2013 to 2019 was estimated in order to study the interannual sardine egg distribution variability along the surveyed area. The PELACUS acoustic survey time-series takes place annually in spring (March–April), in the northern area, covering the same geographical range than SAREVA survey. The survey design for CUFES sampler, consisted in a grid with systematic parallel transects, separated by 8 nautical miles, perpendicular to the coastline, covering the continental shelf, and samples were collected every three nautical miles while acoustically prospecting.

For each year, the centre of gravity has been calculated as a weighted average depending on the location of each sample (density of eggs on the surface as weight factor) according to Woillez *et al*. (2007). Due to the particular topography of the northern Spanish coast, instead of latitude and longitude, depth has been used as well as a distance variable to determine eggs location.

The sardine egg density was grouped in two strata, the eastern (8cEwE, 8ceE, 8b) and western (9aN, 8cW, 8cEwW) strata with a cut-off point around the Cape Peñas and the relative egg density contribution in each of the strata was estimated. The Cape Peñas corresponds to the westernmost limit sampled by BIOMAN survey (AZTI DEPM survey for anchovy).

Analysis of sardine DEPM SSB series (PT-DEPM-PIL and SAREVA) used for sardine assessment in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters- Stock pil.27.8c9a)

The annual relative contribution of the PT-DEPM-PIL and the SAREVA surveys to the total SSB estimates was analysed. The correlation between SSB estimates for each strata, each survey and even between acoustic and DEPM methods, was also checked. Linear regression model with and without intercept were applied to those SSB series, when significant correlation was obtained. Finally the model with the lower AIC was selected in order to scale the SSB estimated by Portugal in 2020 up to the total of divisions 9.a and 8.c.

Results

Sardine eggs from CUFES in PELACUS acoustic survey (2013-2019)

The centres of gravity of the sardine eggs abundance (Figure 2) are located in Atlantic waters (9aN and 8cW) regardless of their total quantity, with 40 to 90% of the eggs located in the 9aN and 8cW. An exception was the year 2015 that can be considered an anomaly as 60% of the eggs were located in the most distal part of the Bay of Biscay this year, although the contribution of the subdivision 9aN was not very significant (barely 15%). Likely this anomaly was because this year the platform was not covered by the survey. In 2016, the sampling intensity was reducing by half and the eastern part of the sampling area (8b and 8.c.E.e) was not covered.

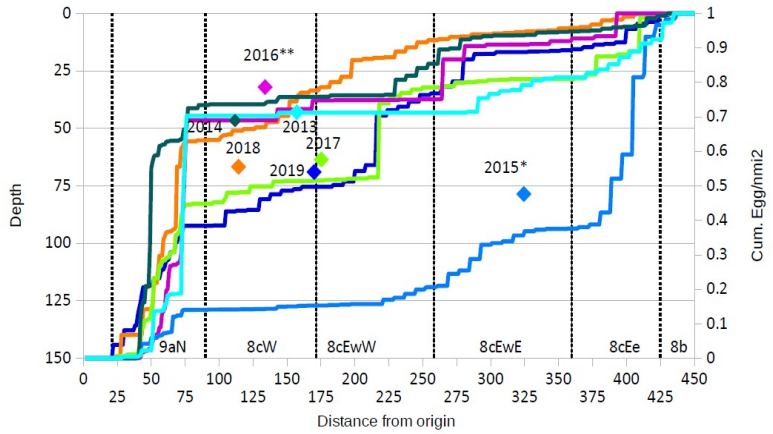

Figure 2: Centre of gravity of sardine egg density (* in 2015 the 9aN platform was not covered; ** in 2016 in addition to reducing the sampling intensity by half, the eastern part of the sampling area – 8.b and 8.c.E.e - was not covered).

According to the temporal variation of egg distribution in the PELACUS surveyed area (excepting 2015 anomaly), the western stratum contribution to the total egg abundance was 40-45% in 2013 and 2016; since then, its contribution increased until almost 90% in 2018, decreasing to 65% in 2019 (Figure 3).

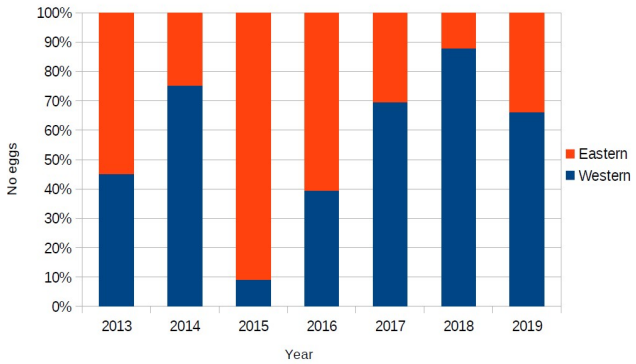

Figure 3. Relative values of sardine annual eggs density estimated by stratum (western: 9aN, 8cW, 8cEwW, eastern: 8cEwE, 8ceE, 8b) from the CUFES sampler in PELACUS acoustic survey. In 2015 the 9aN platform was not covered, in 2016 in addition to reducing the sampling intensity by half, the distal part of the sampling area (8.b and 8.c.E.e) was not covered.

<u>Sardine DEPM SSB series (PT-DEPM-PIL and SAREVA) used for assessment in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters- Stock pil.27.8c9a)</u>

The contribution of the Portuguese area (9.a.S and 9.a.W) to the total SSB used for Iberian sardine stock assessment has been higher than the contribution of the Spanish area along the serie. Comparing SSB indices estimated in both surveys along the time series it is observed that SSB from the PT-DEPM-PIL survey represents in mean the 78 % of the total SSB (Figure 4b), while the contribution of the division 9.a.W to the total SSB is 36 % on average (Figure 4a).

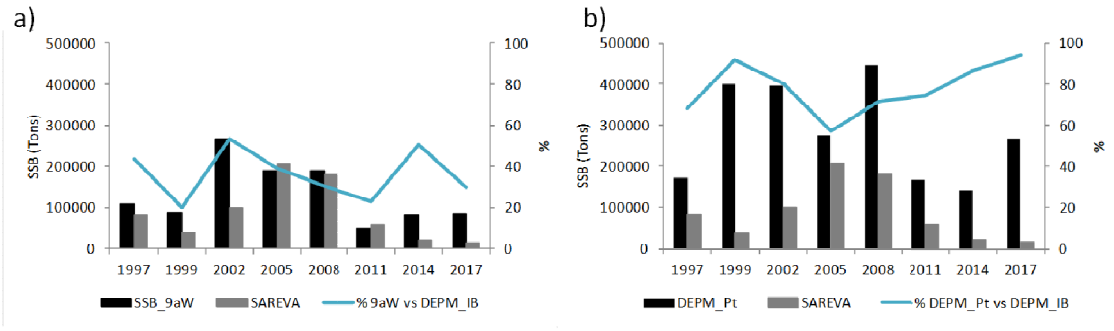

Figure 4. SSB indices (bars) and contribution in % (blue line) of the a) 9.a W and SAREVA and b) the Portuguese surveyed area (DEPM_Pt)and SAREVA to the total SSB used for Iberian sardine assessment.

The correlations between SSB estimates for each stratum, each survey and even between acoustic and DEPM methods inspected were not significant in most of cases, excepting the SSB in the 9.a.W subdivision, which represents the closet area to the one not sampled by the SAREVA survey in 2020, and the total SSB of the Portuguese DEPM survey that was significantly correlated to the total SSB estimates in the Cantabrian Sea (SSB 9.a.N-8.c, r^2=0.68) and Atlantic Iberian waters (DEPM_IB, r^2=0.91) respectively.

Linear regression model between the DEPM SSB of Portuguese survey (DEPM_Pt) and the total DEPM surveys in the Iberian Peninsula (DEPM_IB) with and without an intercept and the corresponding AIC are shown in figure 5 and table 1. According to the lower AIC value, the models without intercept are selected as the best option to scale the SSB.9aW and the SSB_DEPM-Pt up to the SAREVA SSB (Model 2) and to the total Iberian SSB (Model 4) respectively.

Table 1. Summary of the linear regression models between SAREVA survey and the western stratum of the Portuguese survey (SSB.9aW) and the total Iberian DEPM SSB estimates (DEPM_IB) against the Portuguese DEPM survey (DEPM_Pt, covering subdivisions 9.a.W and 9.a.S).

Model		Estimate	Std. Error	t value	Pr(>|t|)		R^2_{adj}	AIC
Model 1 SAREVA ~ SSB.9aW	(Intercept)	1.14E+03	4.36E+04	0.026	0.9799		0.37	201.6
	SSB.9aW	6.56E-01	2.93E-01	2.241	0.0662	.		
Model 2 SAREVA ~ SSB.9aW -1	SSB.9aW	0.6624	0.1251	5.296	0.0011	**	0.77	199.6
Model 3 DEPM_IB~SSB_DEPM_Pt	(Intercept)	1.92E+04	6.82E+04	0.281	0.7881		0.81	205.0
	SSB_DEPM_Pt	1.24E+00	2.25E-01	5.534	0.0015	**		
Model 4 DEPM_IB~SSB_DEPM_Pt-1	SSB_DEPM_Pt	1.301	0.0765	17.01	5.96E-07	***	0.97	203.1

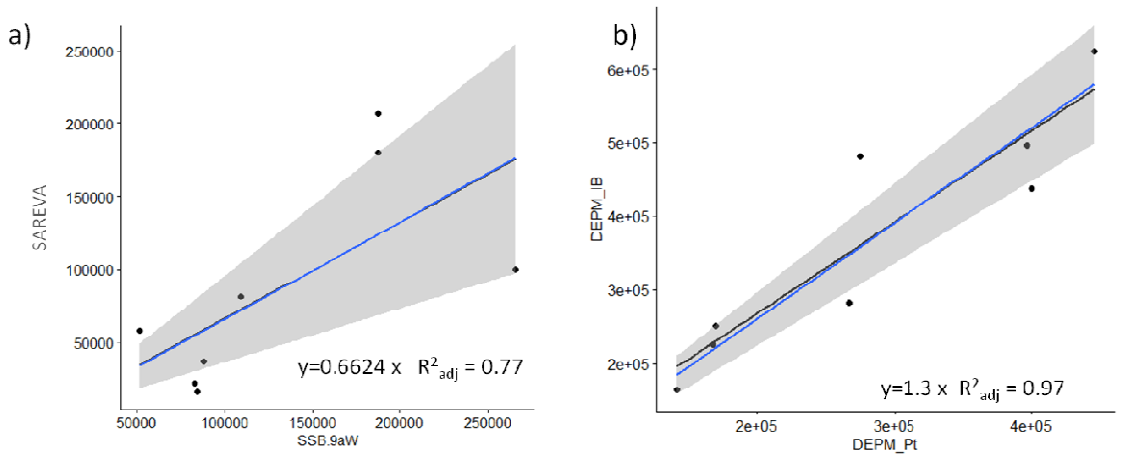

Figure 5. Linear regression models between a) SAREVA survey and the western stratum of the Portuguese survey (SSB.9aW) and b) the total Iberian DEPM SSB estimates (DEPM_IB) against the Portuguese DEPM survey (DEPM_Pt). Shaded areas represent 95% confidence intervals. Blue line: model with an intercept, black line: model without an intercept.

When the modelled SSB series were compared to those historically reported to the assessment, i.e. based on DEPM surveys estimates, is observed that the series estimated by the model 2 and the SAREVA are mismatched(Figure 6a), even showing opposite trends in some years (2005, 2014, 2017). On the contrary, the pattern of the model 4 series matches the DEPM_IB one (Figure 6b). Considering the better match of these two last series and the high correlation between DEPM_Pt and DEPM_IB (r^2=0.97), it was decided to use model 4 to estimate the total SSB in the Iberian sardine stock (9.a-8.c) in 2020 as the best solution for the lack of Spanish data because of the Spanish DEPM survey cancellation.

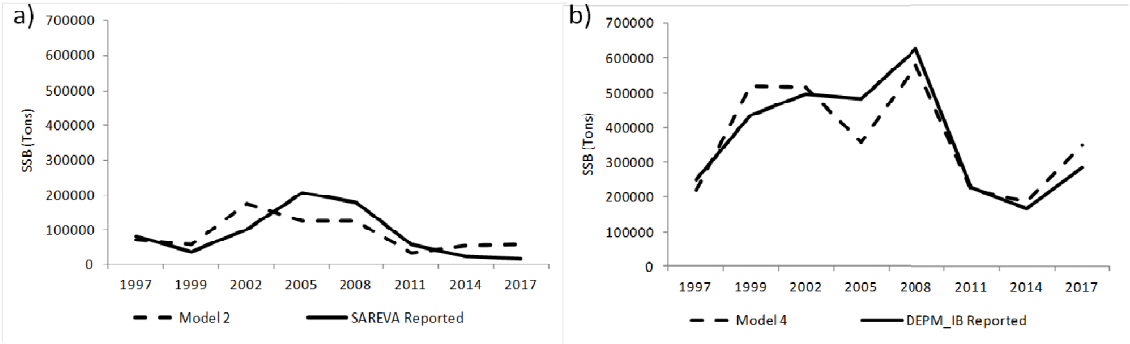

Figure 6. Reported sardine SSB values for a) the SAREVA survey and the model 2 estimates (dashed line) and b) the reported SSB from the total Iberian stock (DEPM_IB) and the model 4 estimates (dashed line).

Discussion

The COVID-19 health crisis and the posterior declaration of the national state of alarm in March of 2020 provoked the cancellation of Spanish spring DEPM survey for the estimation of sardine SSB in the 8.c-9.a.N divisions (SAREVA 0320). This has led to a lack of sardine data for estimating the total stock (9.a-8.c) SSB in 2020 with the impact it has on the assessment for 2021. Different solutions have been tested to compensate this issue.

The first approach was focused on the utility of BIOMAN survey sardine eggs data to estimate a proxy of sardine SSB in the division 8.c. for 2020. BIOMAN survey is delivered in May, mainly focused on divisions 8.abd, although it also covers partially the subdivision 8.c., more specifically the central and eastern part of the division (ICES, 2020b). After analyzing distribution of sardine eggs along the Cantabrian Sea by using data from the CUFES sampler in the PELACUS surveys serie, our results locate consistently the centre of gravity of egg distribution in the subdivision 8.c.W, out of the focus of BIOMAN survey. Moreover, the spawning area and total egg production estimated by SAREVA and BIOMAN surveys in the overlapping area of the division 8.c. cover by both surveys between 2008 and 2017 did not show good correlations (results not presented in this WD). Additionally, the BIOMAN survey takes place in May, out of the peak of sardine spawning season in the area that happens between March and April (Bernal et al., 2007, Coombs et al., 2006, Stratoudakis et al., 2007), and reproductive data of adult females are not collected during it, preventing us to estimate the corresponding reproductive parameters (maturity, fecundity and spawning fraction) required by the Daily Egg Production Method to calculate SSB. Although adult parameters from the Portuguese survey (PT-DEPM20-PIL) delivered in February in the 9.a.division are available, seasonal and spatial variability of fecundity and spawning fraction do not allow combining this data to the eggs collected in May by BIOMAN to estimate SSB in the 8.c.

Taking into account all these issues, sardine egg data collected by the BIOMAN survey are not considered as part of the solution to the lack of Spanish data in 2020.

However, the methodology adopted in the last Iberian sardine assessment (ICES, 2020) to face the problem of the lack of acoustic data in 2020 in subdivisions 9aN and division 8c, scaling the population in numbers of the Portuguese index up to the total Iberian sardine abundances, has been adapted to the SSB DEPM series, tested and resulted statistically significant. The Portuguese survey represents the majority of the SSB in the Cantabrian Sea and Atlantic Iberian waters (mean = 78%) and there is a significant correlation between sardine SSB from the Portuguese survey and the total Iberian SSB (r^2=0.97), concluding that the Portuguese index could be raised by a linear regression model to accommodate the lack of the SAREVA estimations in 2020.

References

Bernal, M., Stratoudakis, Y., Coombs, S., Angelico, M., Lago de Lanzós, A., Porteiro, C., Sagarminaga, Y., et al. 2007. Sardine spawning off the European Atlantic coast: characterization of and spatio-temporal variability in spawning habitat. Progress in Oceanography, 74: 210–227.

Bernal, M., Stratoudakis, Y., Wood, S., Ibaibarriaga, L., Uriarte, A., Valdés, L., and Borchers, D. 2011. A revision of daily egg production estimation methods, with application to Atlanto– Iberian sardine. 1. Daily spawning synchronicity and estimates of egg mortality. ICES Journal of Marine Science, 68: 519–527.

Checkley, D. M., Ortner, P. B., Settle, L. R., and Cummings, S. R. 1997. A continuous, underway fish egg sampler. Fisheries Oceanography, 6: 58-73

Coombs, S.H., Smyth, T., Conway, D., Bernal, M., Stratoudakis, Y., Alvarez, P., 2006. Spawning season and temperature relationships for sardine (Sardina pilchardus) in the eastern North Atlantic. Journal of the Marine Biological Association of the United Kingdom 86 (5), 1245–1252.

Cunha, M. E., Figueiredo, I., Farinha, A., and Santos, M. 1992. Estimation of sardine spawning biomass off Portugal by the Daily Egg Production Method. Boletín del Instituto Español de Oceanografía, 8: 139–153.

García, A., Pérez, N., Lo, N. C. H., Lago de Lanzos, A., and Sola, A. 1992. The Egg Production Method applied to the spawning biomass estimation of sardine, *Sardina pil-chardus* (Walb.) on the North Atlantic Spanish coast. Bo-letín del Instituto Español de Oceanografía, 8: 123–138.

ICES. 2004. The DEPM Estimation of Spawning-Stock Biomass for Sardine and Anchovy. ICES Cooperative Research Report, No. 268. 91 pp.

ICES, 2005. Report of the Study Group on the Estimation of Spawning Stock Biomass of Sardine and Anchovy (SGSBSA). Annex 2: Sardine POF stages, pp.76-77.

ICES. 2006. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas VIII and IX, 24–28 October 2005, Vigo, Spain. ICES CM 2006/LRC:01. 126 pp.

ICES. 2017. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8, and 9. WGACEGG Report 2016 14-18 November 2016. Capo Granitola, Sicily, Italy. ICES CM 2016/SSGIEOM:31. 326 pp.

ICES. 2020. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). Draft report. ICES Scientific Reports. 2:41. 513 pp. http://doi.org/10.17895/ices.pub.5977. Publication of thefull report is expected end of 2020.

ICES. 2020b. Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES areas 7, 8 and 9 (WGACEGG; outputs from 2019 meeting). ICES Scientific Reports. 2:44. 490 pp. http://doi.org/10.17895/ices.pub.6025

Lasker, R., 1985. An Egg Production Method for Estimating Spawning Biomass of pelagic fish: Application to the Northen Anchovy, Engraulis Mordax. NOAA Technical report NMFS 36:100p.

Massé, J., Uriarte, A., Angélico, M. M., and Carrera, P. (Eds.). 2018. Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 –Towards an ecosystem approach. ICES Cooperative Research Report No. 332. 268 pp. https:// doi.org/10.17895/ices.pub.4599.

Miranda, A., Cal, R. M., and Iglesias, J. 1990. Effect of temperature on the development of eggs and larvae of sardine *Sardina pilchardus* (Walbaum) in captivity. Journal of Experimental Marine Biology and Ecology, 14: 69–77.

Simmonds, E. J., and MacLennan, D. N. 2005. Fisheries Acoustics.Theory and Practice. Blackwell Publishing, Oxford.

Stratoudakis, S., Coombs, S., Lago de Lanzós, A., Halliday, N., Costas, G., Caneco, B., Franco, C., et al., 2007. Sardine (*Sardina pilchardus*) spawning seasonality in European waters of the northeast Atlantic. Marine Biology, 152: 201–212.

Woillez, M., Poulard, J. C., Rivoirard, J., Petitgas, P., and Bez, N. 2007. Indices for capturing spatial patterns and their evolution in time, with application to European hake (*Merluccius merluccius*) in the Bay of Biscay. ICES Journal of Marine Science, 64: 537–550.